Replacement of the descending aorta: Recent outcomes of open surgery performed with partial cardiopulmonary bypass

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Objective: Surgical replacement is our standard treatment for descending aortic aneurysm, despite the advent of thoracic endoprostheses. We retrospectively analyzed outcomes of descending aortic replacement performed with partial cardiopulmonary bypass.

Methods: Since 1994, a total of 113 patients in our institution (mean age 68 ± 12 years, n = 75 male) have undergone graft replacement of the descending aorta for nondissecting aneurysm. There were 16 emergency cases (14.2%). All operations were performed through left thoracotomy with partial cardiopulmonary bypass with segmental clamping. Since 1998, preoperative magnetic resonance angiography has been performed to detect the Adamkiewicz artery in elective cases. Motor evoked potentials are now measured intraoperatively.

Results: Early mortalities were 5.3% overall (6/113), 1.0% (1/97) in elective cases, and 31.3% (5/16) in emergency cases. Rates of spinal cord dysfunction were 2.7% overall (3/113), 1.0% (1/97) in elective cases, and 12.5% (2/16) in emergency cases. Stroke rates were 7.1% overall (8/113), 4.1% (4/97) in elective cases, and 25.0% (4/16) in emergency cases. Rates of respiratory failure were 9.7% overall (11/113), 9.2% (9/97) in elective cases, and 12.5% (2/16) in emergency cases. No patient underwent reoperation for the same lesion as a result of repair problems in the follow-up period. Kaplan–Meier overall survival estimates were 92.2% at 3 years, 90.6% at 5 years, and 70.2% at 10 years.

Conclusion: Although it is more invasive than stent graft repair, descending aorta replacement performed with partial cardiopulmonary bypass involves a risk comparable to that associated with thoracic endoprosthesis placement.

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Surgical treatment for a descending thoracic aneurysm (DTA) is changing drastically in response to the advent of endovascular treatment. Endoprostheses have been used for DTA, with generally favorable results.[1,2] Stent graft repair for thoracic aortic diseases is a therapeutic option even for high-risk patients who are not candidates for open surgery. Open surgical replacement, however, is still our current standard treatment for DTA. There are several operative strategies for DTA, such as the single-clamp technique,[3] distal perfusion with left heart bypass,[4] hypothermic circulatory arrest,[5] and partial cardiopulmonary bypass (PCPB).[6] We have usually used PCPB for DTA, with hypothermic circulatory arrest when there is no space for crossclamping. We retrospectively analyzed the outcomes for DTA repair performed with PCPB and compared them with those reported in the literature for endoprostheses.

Materials and Methods

Patients

From 1994 to 2004, a total of 113 patients (75 men, mean age 68 ± 12 years) underwent graft replacement of the descending aorta for nondissecting aneurysm. The cases that required open

Abbreviations and Acronyms
AKA = Adamkiewicz artery
DTA = descending thoracic aneurysm
MEP = motor evoked potential
PCPB = partial cardiopulmonary bypass

proximal anastomosis under circulatory arrest were excluded, and the patients in this study had sufficient space for crossclamping next to the left subclavian artery and celiac artery. There were 16 cases of emergency surgery (14.2%), all because of rupture of the aneurysm. Fifteen patients had undergone previous abdominal aortic replacement, 3 had undergone previous thoracoabdominal aortic replacement, and 11 had undergone previous thoracic aortic replacement. Since 1998, preoperative magnetic resonance angiography has been performed to detect the Adamkiewicz artery (AKA) in elective cases.[7] The AKA was preoperatively imaged by contrast magnetic resonance angiography with gadolinium dimeglumine (0.3 mmol/kg body weight). Early- and late-phase images were used to differentiate arteries from veins. Imaging volumes covered the levels between T6 and L3. The AKA and the anterior spinal artery were identified by at least two radiologists in 0.6-mm contiguous sections processed by multiplanar reconstruction. Our institution approved this retrospective study and did not require patient consent on the condition that patients not be identified.

Operative Techniques

The patients were anesthetized and intubated with a double-lumen endotracheal tube. The patients were then positioned in the right lateral decubitus position with the hips flexed 60°. An incision was made from the vertebral border of the scapula to the costal cartilage along the intercostal space. From the 4th to the 7th intercostal space, access to the left thorax was selected according to the location of the aneurysm. The left or right femoral artery and vein were dissected and looped with umbilical tape. A cannula was inserted in the femoral artery for perfusion inflow, and another cannula was inserted in the femoral vein for perfusion outflow. The tip of the venous cannula was placed at the opening of the inferior vena cava in the right atrium, with placement confirmed by transesophageal echocardiography. PCPB was initiated, and normal proximal aortic pressure was maintained; the flow rate was usually around 1.5 to 2.0 mL/(min · m^2). The pump circuit had an extracorporeal membrane oxygenator, including a heat exchanger. The bladder temperature was cooled to between 33°C and 34°C during PCPB.[8] The DTA was exposed and clamped after establishment of PCPB. The clamps were placed sequentially when the aneurysm involved a long segment. The aorta was opened longitudinally, and intercostal arteries were ligated or oversewn for hemostasis when they were considered to be unimportant. Intercostal arteries that had to be reattached or preserved were temporarily closed with a bulldog clamp or small balloon-tip catheters. The anastomosis was always performed with complete transection of the descending aorta. An appropriately sized Dacron polyester fabric graft was chosen, and the proximal anastomosis was performed first with running 3-0 or 4-0 polypropylene suture with a polytetrafluoroethylene felt strip. Intercostal arteries were reattached with a short, small-caliber graft. The distal anastomosis was then performed with running 3-0 or 4-0 polypropylene suture with a polytetrafluoroethylene felt strip. The flow of PCPB was reduced, and the aortic clamps were then gently released. The patient was weaned from PCPB once the bladder temperature reached 36.5°C.

We have been measuring motor evoked potentials (MEPs) during surgery since 1998 to detect spinal ischemia and have previously described the details.[9] With sufficient anesthesia maintained with low doses of fentanyl (0.02–4 mg/kg), propofol (4—6 mg/[kg · h]), and vecuronium (0.04 mg/[kg · h]), the motor cortex was activated by 600 V transcranial electrical stimulation. The action potentials conducted through the anterior horn motor neurons were recorded from the skin over the upper extremity muscles (as a control), the lower extremity muscles, and the thenar muscles. The signals of the MEPs are affected by femoral arterial cannulation; the probe was therefore always placed on the contralateral side from femoral cannulation. Monitoring of MEPs is also influenced by anesthesia, including neuromuscular blockade, only a low dose of vecuronium was therefore used during the operation. During crossclamping, MEP levels were determined every 2 to 5 minutes. A fall in MEP amplitude below 25% of the baseline was taken to indicate ischemia of the spinal cord. When critical reduction of MEP amplitude was observed, rapid revascularization of the spinal cord blood supply was performed. Additionally, the blood pressures of upper and lower body were increased with use of catecholamines, transfusion, and perfusion flow.

Definitions

Early mortality was defined as death during the hospital stay. Postoperative stroke was defined as newly developing neurologic deficit confirmed by computed tomography. Neurologic diagnoses were made by neurologists. Respiratory failure was defined as the need for intubation and ventilatory support longer than 72 hours.

Statistical Analysis

Values are the mean ± SD. Data were analyzed with Fisher exact tests for categorical variables.

Results

The early mortalities were 5.3% overall (6/113), 1.0% (1/97) in elective cases, and 31.3% (5/16) in emergency cases. The rates of spinal cord dysfunction were 2.7% overall (3/113), 1.0% (1/97) in elective cases, and 12.5% (2/16) in emergency cases. Spinal cord dysfunction occurred more frequently in patients older than 75 years and was not prevented by preoperative AKA detection (Table 1). The stroke rates were 7.1% overall (8/113), 4.1% (4/97) in elective cases, and 25.0% (4/16) in emergency cases. Stroke occurred most frequently in emergency cases, but it was not related to crossclamping adjacent to the aortic arch (Table 2). The rates of respiratory failure were 9.7% overall (11/113), 9.2% (9/97) in elective cases, and 12.5% (2/16) in emergency cases.

Thirty-two patients were older than 75 years, and 9 of these underwent emergency operations. The older patients' mortality was 6.3% (2/32), and the 2 patients who died had both undergone emergency operations. The rates of spinal

TABLE 1. Spinal cord dysfunction and variables

	Total	Spinal cord dysfunction	*P* value
All	113	3 (2.7%)	
Male	76	3 (3.9%)	.55
Age			
>70 y	56	3 (5.4%)	.12
>75 y	32	3 (9.4%)	.02
Partial cardiopulmonary bypass duration			
>60 min	83	3 (3.6%)	.99
>90 min	39	1 (2.5%)	.99
>120 min	15	1 (6.7%)	.36
Emergency operation	16	2 (12.5%)	.05
Preoperative Adamkiewicz artery detection	50	2 (4.0%)	.59

cord dysfunction in this age group were 9.3% overall (3/32), 4.3% (1/23) in elective cases, and 22.2% (2/9) in emergency cases. The stroke rates were 9.4% overall (3/32), 0% (0/23) in elective cases, and 33.3% (3/9) in emergency cases. The rates of respiratory failure were 12.5% overall (4/32), 13.0% (3/23) in elective cases, and 11.1% (1/9) in emergency cases.

Overall, the mean operative time was 291 ± 93 minutes, the mean PCPB time was 84.8 ± 32.1 minutes, the mean bleeding volume was 1187 ± 1432 mL, and the mean transfusion volume was 1335 ± 2642 mL, with 45.1% of the patients not requiring transfusion. In elective cases, the mean operative time was 280 ± 78 minutes, the mean PCPB time was 80.7 ± 27.7 minutes, the mean bleeding volume was 921 ± 845 mL, and the mean transfusion volume was 851 ± 1870 mL, with 51.5 % of the patients not requiring transfusion.

Magnetic resonance angiography was performed in 65 cases, and the AKA was detected in 50 patients (76.9%). Among these patients, 2 had paraplegia; the AKA had been detected in both. Three patients had paraplegia or paraparesis; 1 had undergone surgery without MEP monitoring, another showed MEP change, and the third patient showed no change in MEPs. MEPs were altered in 2 patients; 1 had paraplegia and the other had a postoperative stroke.

None of the patients underwent reoperation for the same lesion to repair problems in the follow-up period. Kaplan–Meier overall survival estimates were 92.2% at 3 years, 90.6% at 5 years, and 70.2% at 10 years (Figure 1).

Discussion

DTA repair is usually discussed in combination with thoracoabdominal aortic aneurysms. Reports focusing solely on surgical repair for DTA are relatively uncommon. Many DTAs will probably be repaired with endoprostheses, because a DTA has no visceral branches. The advent of endovascular treatment is believed to be a great innovation in treatment for aortic aneurysm. Endoprostheses have been used for abdominal aortic aneurysms, and some surgeons are now using them for DTA repair. Makaroun and colleagues[2] used the GORE TAG thoracic endoprosthesis in 139 patients with DTA. They reported that the procedure time was 150 minutes on average, blood loss was 506 mL on average, and that mortality, stroke, and spinal ischemia rates were 1.5%, 4% and 3%, respectively. Fattori and colleagues[10] used the Talent thoracic stent graft for DTA in 457 patients. They reported mortalities of 7.9% in acute cases and 4% in elective cases, a stroke rate of 3.7%, and a spinal ischemia rate of 1.7%.

The articles on endoprostheses refer to open repair of DTA, and they often point out that the mortality associated with open repair is greater than 10% and that the risk of spinal ischemia is 4% to 5%. On the other hand, the results of open repair are improving. Coselli and colleagues[11] reported a mortality of 4.4% and a paraplegia rate of 2.6% after open repair of DTA. Estrera and associates[12] reported a mortality of 8.8%

TABLE 2. Stroke and variables

	Total	Stroke	*P* value
All	113	8 (7.1%)	
Male	76	5 (6.6%)	.72
Age			
>70 y	56	4 (7.1%)	.99
>75 y	32	3 (9.4%)	.69
Partial cardiopulmonary bypass duration			
>60 min	83	8 (9.6%)	.20
>90 min	39	5 (12.8%)	.13
>120 min	15	3 (20.0%)	.08
Emergency operation	16	4 (25.0%)	.01
Crossclamp near arch	37	4 (10.8%)	.43

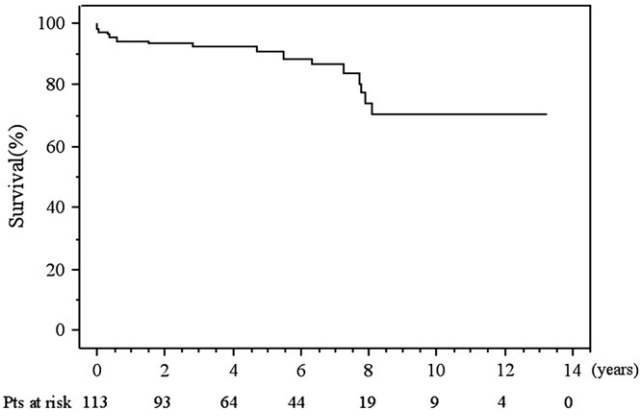

Figure 1. Kaplan–Meier cumulative actuarial survival curve.

and a paraplegia rate of 2.7% after open repair of DTA with cerebrospinal fluid drainage and distal perfusion. Even with hypothermic circulatory arrest, Patel and coworkers[13] reported a mortality of 6.0%, a stroke rate of 6.8%, and a spinal ischemia rate of 4.5%. Our results were comparable with or even better than those reported for open repair and for endoprostheses. Open repair of DTA has several merits relative to repair with an endoprosthesis, especially long-term durability. Moreover, there are no anatomic limitations such as interfere with the applicability of an endoprosthesis, including short or wide proximal or distal landing zones, severe neck angulations, and tortuous or stenotic access arteries.[14]

Stroke is a devastating complication after aortic surgery. The incidence and etiology of stroke related to DTA repair have not been frequently described. Attention is generally paid to spinal ischemia as a primary neurologic complication of DTA repair. Actually, DTA repair with PCPB involves a certain risk of stroke, as indicated in this study. Goldstein and colleagues[15] reported a stroke rate of 8.1 % in DTA repair and also noted that stroke was a significant predictor of postoperative death. Patel and coworkers[13] reported a stroke rate of 6.8% in DTA repair with hypothermic circulatory arrest. The retrograde flow of PCPB from femoral cannulation when normal proximal aortic pressure is not maintained could be a reason for the stroke risk. Moreover, crossclamping adjacent to the aortic arch has also been mentioned as a cause of stroke.[16] In our study, however, some patients without crossclamping adjacent to the aortic arch still had stroke occur under normal proximal aortic pressure. Crossclamping adjacent to the aortic arch was not a statistically significant risk factor of stroke in our study.

The preoperative detection of AKA by magnetic resonance angiography is, we believe, useful in preventing spinal cord injury during DTA repair. The utility of the detection of AKA has already been described elsewhere, and the effects were reflected in the lower rate of spinal ischemia. Although the spinal blood supply is not completely understood, we consider that reimplantation or preservation of the intercostal arteries, which connect the AKA, contributes to improved results. In this study, however, 2 patients showed spinal ischemia despite detection of the AKA. This implies that preservation of the AKA per se is not enough to prevent spinal ischemia. MEPs have been reported to be a rapid indicator of spinal cord injury during thoracoabdominal aortic repair.[17] We also believe that MEP monitoring contributes to prevention of spinal cord injury, even during DTA repair, but such an effect was not clear in this study.

Advanced age is supposed to be among the risks for DTA repair. Huynh and colleagues[18] reported a stroke rate of 9% in their series of descending and thoracoabdominal aortic replacements in patients of advanced age. In this study, the frequencies of stroke in patients older than 70 years and in those older than 75 years old were comparable. No deaths and no postoperative strokes were seen among elective cases. The rate of respiratory failure, however, was high even in elective cases, as expected.

In conclusion, outcomes of traditional open DTA repair are improving. The long-term result of this technique is in clear contrast to that of endoprosthesis. Even in patients older than 75 years, open DTA repair can be performed with acceptable risk. Although open DTA repair is by definition more invasive and should be further improved, the risks involved in replacement of the descending aorta under PCPB were comparable to those associated with thoracic endoprosthesis placement at this time.

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